Applications of Non-Contact Magnetising on Ring Shaped Components

A Paper By

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1 Introduction

Magnetic Particle Inspection of ferro-magnetic components still is the most common method of Non-destructively testing for surface breaking defects in that material. Such defects can be introduced into the component during the manufacturing process or induced by stress and fatigue in subsequent service.

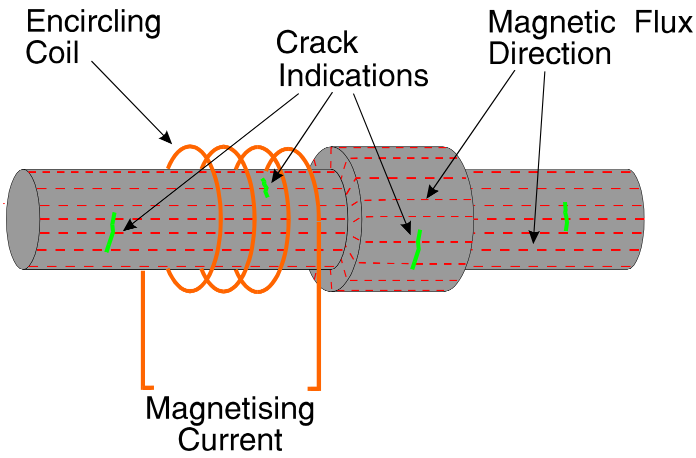
A surprisingly large number of components submitted to MPI tests are circular in cross section and have holes in central or otherwise. This paper details a method of testing such subjects in a manner which, with a high degree of confidence, reveals linear discontinuities on all surfaces via a single process without resorting to high current contact.

Magnetic Particle Inspection is by its very nature a fail to danger system in that if after the testing process has been carried out there are no visible indications of discontinuities then either there are no defects in the component or the testing process has not been defined, or carried out, correctly.

The standard parameter for magnetising is generally associated with the strength of the magnetic field. This is understandable since it is only this that can be allocated a numerical value. ASTM E1444 quotes 30-60 G (2.4 to 4.8 kA/m) tangential field strength. The technique is a very forgiving one in that satisfactory results can be obtained over a wide range of magnetising values as demonstrated by the range of values given. It is stressed that this field strength is to be present in all areas.

A factor which is not given the same degree of emphasis is the direction of the magnetic field. ASTM E1444 appears to stipulate that suspected discontinuities should be within 45^o to the direction of magnetisation. However it is not appreciated understood that between 0^o and 45^o even there is a reduction in sensitivity with increasing angle. This is more pronounced in clean cracks in fine grained material where the crack varies little microscopically from the main direction. Usually but not invariably cracks tend to follow grain boundaries so there will be a range of angles within a single crack. So in relatively coarse grained material, some component of the crack will be in the optimum orientation.

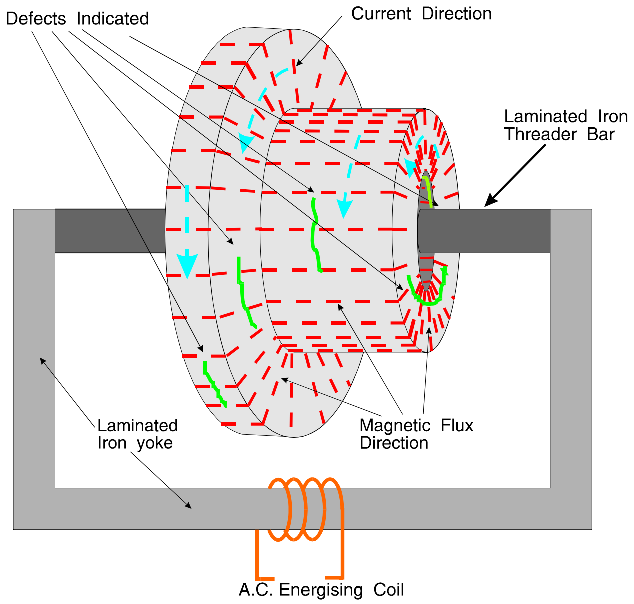
In indirect magnetisation the direction of the field is considerably influenced by the shape of the component, particularly in encircling coil magnetising of complex shaped parts. This is evidenced in the longitudinal magnetising components in which the flux enters the component perpendicular to the surface at some distance away from the coil.



E1444 has coil incremental formulae for testing purely cylindrical parts but, for very good reasons does not address parts with varying cross section. An encircling coil will not induce a field in the required direction to reveal circumferential flaws on the end face or sections of the part not longitudinal.

2 Induced Current Magnetising

The common method of magnetising such an area is by direct magnetising by current flow across the diameter of the part with generally a number of shots at different positions. Whilst this reveals any end defects it is of course a contact magnetising process and therefore subject to the risk of overheating at the contact points. Also in slender components there is a risk of distortion due to the necessary pressure to maintain good electrical contact. These factors are of considerable significance particularly in aero engine parts which have a majority of components circular in shape. In solid parts this drawback can some times be overcome by magnetic flux flow.



For parts with holes a more efficient method is the induced current method in which current is induced to run round the circular part by a laminated yoke threader bar system energised by an AC coil around one limb of the yoke. As illustrated above.

This technique is also referred to as the transformer technique since the component being magnetised forms a single shorted secondary turn of a transformer with the energising coil being the primary and conduction of the flux by means of the laminated iron yoke. Obviously this operates more efficiently with AC applied to the primary - the laminations preventing significant losses by eddy currents - though half wave rectified DC may function adequately.

The current flowing around the component induces a magnetic flux perpendicular to the current and the flux flows in a toroidal direction. Thus any discontinuities on the edge of the material, sections near parallel to the ends and along the longitudinal surface will be indicated.

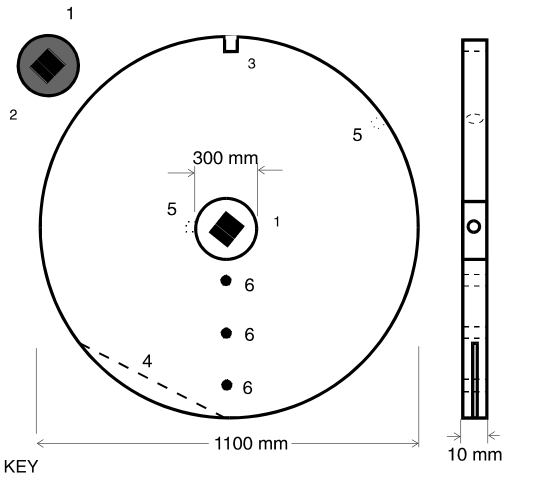
Since the component is in effect a single secondary shorted turn, extremely high amperages can be obtained flowing round the circuit. For example a yoke energising coil of 150 turns carrying 65 amps will induce over 2,000 amps AC RMS in a disc 1,000mm in diameter by 12mm thick with a central hole of 150mm diameter. On small components 300 Amps can be induced in components 2" O.D. Tests show that these values and directions will reveal circumferential defects on all appropriate surfaces.

We would mention at this stage our system of the determination of the efficiency and direction of the magnetic field. We have found difficulties in a number of aspects with the two common methods of a separate indicator for example as the Pie-field Indicator or the Strip Indicators since these when used in an indirect magnetising situation will indicate the inducing field rather than the field which exists in the surface of the part. A further disadvantage is that such indicators can only be used on horizontal surfaces. The other method is by Hall Effect measurements which have the same drawback in that they measure only the field which exists in the air adjacent to the part whether this is leakage or induced. A further difficulty with the Hall Effect method is ensuring the Hall Effect sensor is aligned correctly.

Our preferred method is to include an artificial defect in a sample subject. This is a drilled hole of, say, 5mm diameter to a depth of approximately 5mm then tightly plugged with a circular piece of the same material.

This usually means that the plug has to be hammer peened over so that the plug is tightly held within the hole. The surface is then dressed to ensure that there is no visible evidence of the line of contact of the plug with the material. Not only does this method determine that the magnetising value is correct but since the plug is circular good indications are obtained of the direction of the magnetising field in the part. We apply this method to many odd shaped components including such things as crankshafts, steering knuckles etc. in which even under the best circumstances the direction of the field cannot be entirely predicted.

It is this method which has been used in our experiments with toroidal fields and which shows that all surfaces will show indications in the circumferential direction.



KEY

1 Laminated iron yoke
2 Energising coil
3 Radial slot 3mm wide, 10mmdeep
4 Edge slot 3mm wide 10mm max.
5 5 mm dia. hole 5mm deep plugged
6 8mm dia. through hole plugged

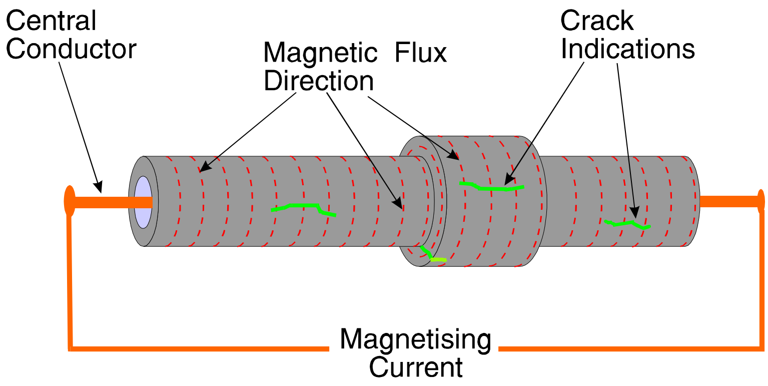
NOTE The holes 5&6 were tapered and plugged with taper pins driven in. The surface was peened then dressed so that the pin area was not discernible to un-aided vision.

The limitation of the induced current method is only the size of the central hole relative to the outside diameter of the component. It will be understood that even with laminations there is a saturation value which depends on the cross section area of the yoke. By experience this limitation can be expressed by the cross of yoke is greater than and equal to the square root of outside diameter of the part to provide a field of 5kA/m.

3 Central Conductor Magnetising

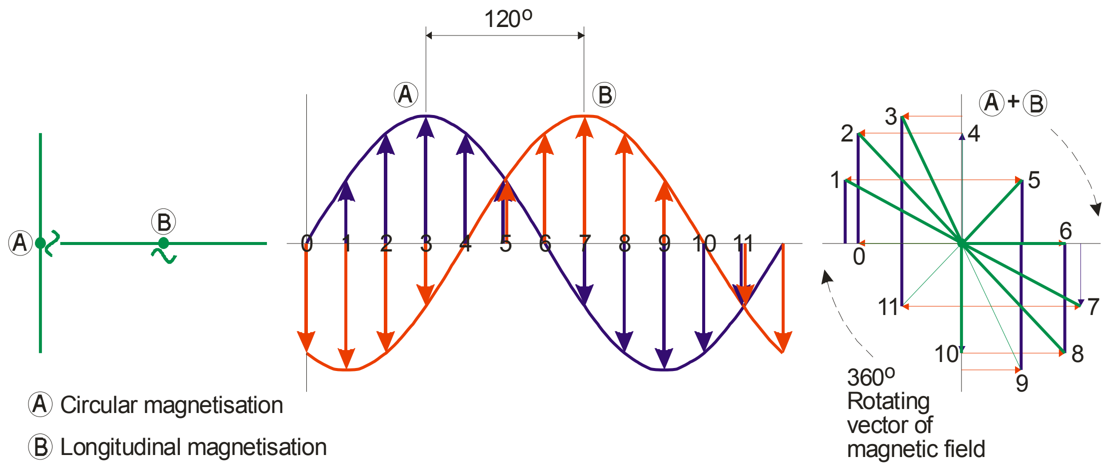
Whilst the induced current method of MPI is not in common usage the magnetisation in the circular direction using a central conductor in the search for longitudinal and radial defects is of course standard non contact technique.

In this technique a conductor (or conductors) carrying high amperage current are passed through the central hole which induces a circular magnetic field in the component to reveal radial and longitudinal defects.

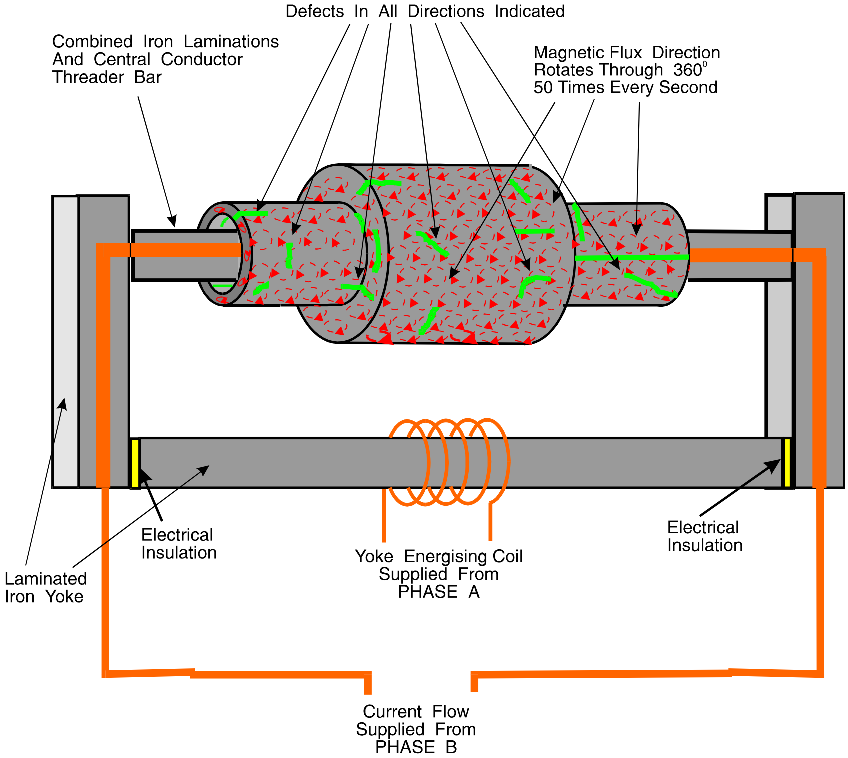


4 Combination of Induced Current and Central Conductor Magnetising

It is possible to combine the above two methods induced current and central conductor into a single magnetising process without contact which requires only one shot to detect all defects regardless of their direction on the surface. Multi-directional magnetising using the Swinging Field rotating vector system is ideal for subjects with central holes. In the Swinging Field system two perpendicular magnetic fields are imposed on the piece in such a manner that the resultant single direction vector changes angle with time. If the two primary fields are derived from different phases of a 3 phase mains supply the field will be perpendicular to any defect 120 turns per second, sufficient to attract particles to the discontinuity edges.



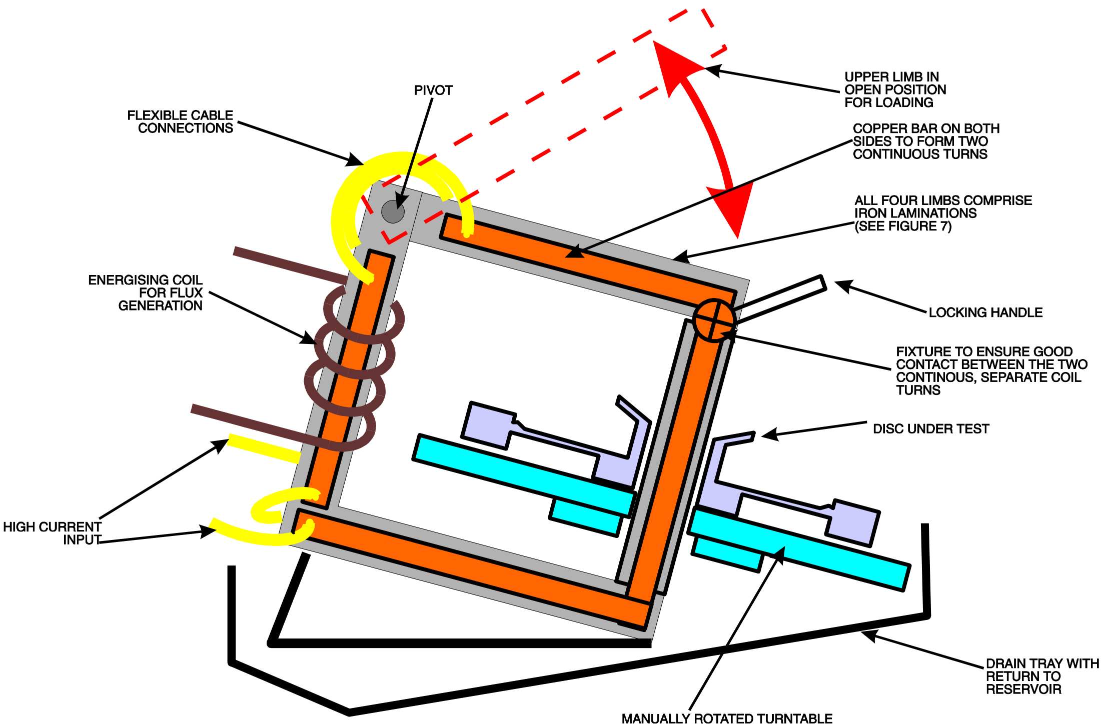
Applied to the magnetising of hollow parts this means that the induced current is derived from one phase of a three phase mains supply and the central conductor current from a different phase. As there is a phase lag the resultant vector of the two simultaneously induced fields changes its angle in direct relation with the magnitude of the flux in each of the primary directions. Therefore with a phase difference of 120° the field will rotate through 360° at mains supply frequency.



In schematic terms a magnetising arrangement is shown. The threader bar is a composite of iron lamination and copper conductor as shown. Since the laminations are conductors it is important that there is insulation between the copper conductor and the lamination. Further to prevent recirculation currents there is insulation between the limbs.

5 A Practical Application of This Method

This technique is perhaps best suited to discs an application to aero-engine discs is shown. The upper limb of the yoke is hinged to allow loading of the disc on to the supporting platen. After loading the upper limb is lowered and locked to ensure good contact between the split turns of the two turns control conductor. The whole system is tilted to permit drainage of the fluid off the disc.



The photograph is of a typical machine for testing railway brake discs. These applications are manual but there is no reason why the system should not be applied to automatic systems.